IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 13, No. 3, September 2024, pp. 2482~2489
ISSN: 2252-8938, DOI: 10.11591/ijai.v13.i3.pp2482-2489

Insight of recent artificial intelligence-based strategy to effectively screen COVID-19

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Article Info

Article history:

Received Dec 19, 2023
Revised Feb 24, 2024
Accepted Mar 12, 2024

Keywords:

Artificial intelligence
Chest x-ray
COVID-19
Pandemic
Screening

ABSTRACT

The recent era of pandemic by corona virus disease (COVID-19) has witnessed a faster evolution of various technological solution to thwart the life-threating situation. The most important step was to select a faster mode of screening COVID-19 using chest x-ray (CXR) which could be actually ten folds faster than conventional invasive screening methods. However, the method of determining the presence of COVID-19 from CXR is critically challenging owing to the dynamic and complex nature of disease. Such problem is attempted to be solved by harnessing the potential of artificial intelligence (AI). Hence, this paper contributes towards discussion of most recent and current implementation strategies formulated by AI models towards diagnosing COVID-19. The study outcome of this paper yields an interesting learning outcome to show that AI models' adoption is increasing in faster pace and yet challenges do exist till date. The outcome of study will assist in better adoption of AI models towards screening COVID-19.

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1. INTRODUCTION

Coronavirus disease or commonly known as COVID-19 that has created a historical pandemic at the year end of 2019 is basically originated from severe acute respiratory syndrome corona virus i.e. SARS-CoV-2 virus [1]. Screening for COVID-19 involves different forms of measures for identifying the infected individual with the virus. The first bigger challenge is asymptomatic spread where an infected patient doesn't exhibit any visible clue of standard infection where its severity is quite higher as its difficult to distinguish from the normal person [2]. The second bigger challenges noted during the recent pandemic era was to balance the resources in order to treat COVID-19 patients while maintaining the essential medical services for other conditions is a significant challenge. Apart from this, there is also an economic impact, social and mental health challenges with emergence of new variants of virus. The most frequently adopted reverse transcription polymerase chain reaction (RT-PCR) test is time consuming and not scalable towards assessing masses of infected person [3]. Hence, chest x-ray (CXR) could be one of the fastest ways to determine the presence of COVID-19. However, CXR being a type of medical images also suffers from various loopholes [4] viz. i) CXR can overlap with other respiratory conditions, ii) higher degree of variability in radiographic appearance while COVID-19 manifest with a wide range of radiographic patterns which vary from one to another individuals, iii) it is also quite eventual that CXR could yield false negative results especially in early stages of infection, iv) there is also a bigger challenges in sensitivity and specificity of CXR images for COVID-19, that may not be as high as RT-PCR, v) there is a larger dependency of stages of development of diseases for COVID-19 that may go undetected by CXR, vi) operator dependencies while capturing CXR and interpreting the outcome is another loopholes, vii) although the dose of radiation for single CXR is relatively low, but when repeated CXR is carried out then the patient is exposed to higher degree of radiation, and viii) there is quite a limited quantitative information associated with lung abnormalities during COVID-19 and hence CXR may not be that helpful for tracking severity and progression of disease. This problem can be solved by using artificial intelligence (AI) as reported in many studies [5]-[7]. The adoption of AI can be used for radiological image analysis along with COVID-19 symptom prediction, drug repurposing and vaccine design, modelling epidemiology using contact tracing and predictive analytics, real-time data analysis, and sentiment analysis.

Irrespective of an AI to be such potential problem-solving method, it is characterized by various research problems in the context of using AI in screening COVID-19. Following are some of the essential research problems and challenges [8]-[10]. i) adoption of AI has a potential dependencies towards data representativeness and its quality while performing training which leads to biases causing unreliable prediction, ii) another significant problem is associated with few abundance of labeled data for training AI models as a precise annotation of COVID-19 cases demands expert input that may not be readily available, iii) there are wider ranges of symptoms for COVID-19 that can eventually vary from one to another person while if the AI-model is generalized to one use-case they may not be applicable for other cases, iv) AI-based models also suffers from over fitting problems when any research model attempts to customize the model to specific training data and hence its reliability is highly questionable when exposed to different data, v) majority of the existing approaches carried out using AI suffers from either explainability issue or interpretability issue without which facilitation of clinical decision-making is quite challenging, vi) none of the existing approaches of AI has discussed its integration with the clinical workflows without which its impractical to understand its operations along with user interfaces and electronic health record systems, vii) AI models also suffers from resource constraint issue where significant computational power and complex algorithm is demanded and hence not all healthcare facilities are expected to have expensive and comprehensive computational resources, viii) there is a limited availability of diverse dataset for screening COVID-19 especially demanded for training its AI-model, ix) finally, validation and clinical trails with the AI model is highly necessary that can extremely time consuming, resource-intensive, and yet may not yield anticipated outcomes.

The research problems have been identified after reviewing some of the related work associated with the study domain. Gouda *et al.* [11] have discussed various deep learning method towards screening CXR for identifying COVID-19. The study outcome suggests that adoption of certain pretrained models (e.g. Alexnet, GoogleNet, and ResNet18) offers accuracy higher than 90% and more and yet they have challenges e.g., data privacy, restricted number of real-time radiological imges, and lack of regulations to conduct automated screening. Jiao *et al.* [12] have discussed about AI usage using clinical data and CXR to diagnose COVID-19 patients. The study model has used deep learning for extracting important features while a predictive modelling is carried out using clinical data. An extensive investigation towards existing AI-based schemes and their extensibility to be useful for screening COVID-19 and its other variants is reported by Khan *et al.* [13]. According to the authors, there are various AI-based schemes that reports usage of multi-stage approaches, segmentation, and classification. Study signifying the usage of medical images towards identifying COVID-19 cases is carried out by Shah *et al.* [14] while the authors conclude the importance of preprocessing and segmentation to have a significant impact towards screening medical images. According to Subramaniam *et al.* [15], convolution neural network (CNN) is considered to offer better performance specially in terms of accuracy. Further, adam optimizer is found to have better influence towards modelling AI-based screening of COVID-19. Similar fact was also noted in Thirukrishna *et al.* [16].

A closer look into the above-mentioned studies shows that they are basically a review-based insight to understand the effectiveness of adopting AI models in screening COVID-19 considering various use-cases of problems. However, there is no effective disclosure of the limiting attributes associated with individual models and interpretation of limiting factors have been generalized. Further, it is essential to understand the recent trends of current years which is unlike to be seen as majority of existing review work compiles the contents based on aggregated years of data. This creates quite challenges in confirming which approaches are more efficient than other as some approaches are found efficient in one paper which is reported less efficient in another. Therefore, the overview of the review work is associated with its contribution towards interpreting only the current and latest research models where different variants of AI has been used which is less reported in existing review work. The value added to this paper are i) explicit discussion of AI-based current research models to gain an insight of individual work effectiveness, ii) visualizing explicit research trends for both AI and non-AI based approaches, and iii) pint-pointed research gaps associated with current published and most related work.

2. METHOD

At present there are various review work which has already presented a comprehensive discussion of AI-based methodologies towards screening COVID-19. Therefore, in order to make a different scale of approach to existing review paper, the proposed review work is conducted using a distinct methodology. A desk research methodology is adopted for this purpose where a series of operation is carried out ranging from collecting the data to shortlisting the discussion of the data. The inclusion criteria formulated for this purpose is to consider only 2023 published papers where implementation model of AI is presented for screening COVID-19. The basic ideology of this review work is to understand the degree of effectiveness of current literatures using a simplified method as exhibited in Figure 1.

A closer look into Figure 1 shows that proposed scheme considers 4 set of keywords to collect primary data from reputed journals which is further classified on the basis of AI and non-AI based models. It is to be noted that the proposed study only emphasizes on AI based models while publication counting of non-AI based model is carried out just to visualize the research trend. It is also noted that primary extraction of research gap is mainly based on AI-based model. The primary data for AI-models is collected for CNN, long short-term memory (LSTM), and transfer learning (TL) to arrive at 2297 research papers. The inclusion criteria consist of only 2023 published implementation papers while the exclusion criteria consist of journals without comprehensive results discussion or devoid of included test parameters. This is done to understand the implementation method with clarity. Finally, it is noted that only 79 papers fullfil the inclusion criteria while applying of exclusion criteria results in 35 number of papers that has been reviewed in current study. Finally, this method results in some interesting learning outcomes in the form of research trend and research gap. The next section presents discussion of the results of proposed review work.

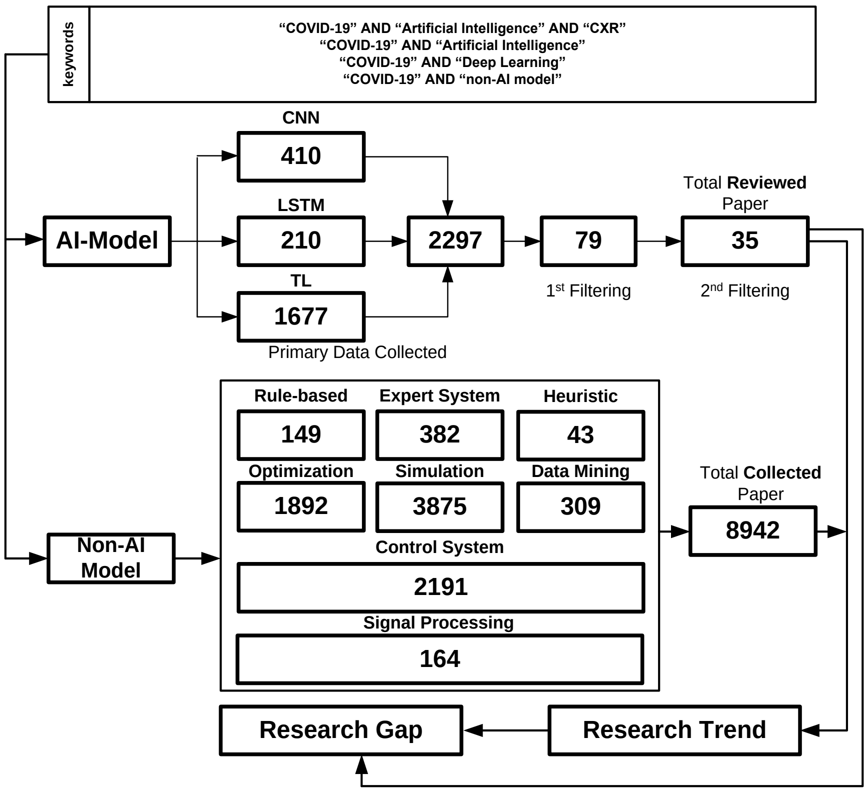


Figure 1. Research methodology adopted

3. RESULTS AND DISCUSSION

This section presents the outcome accomplished from the review work where the prime highlight was to assess the effectiveness of AI-based approaches. Majority of the work reviewed in proposed study is in perspective of investigating the effectiveness of utilizing a chest radiograph in the form of x-ray when subjected to AI-based techniques. It is also noted that various researchers have addressed different set of problems where the core agenda is basically to confirm the presence of COVID-19 infection in the lungs area. This section details the state-of-art AI methods that has been published most recently followed by briefing of research trends and learning outcomes.

3.1. State-of-art artificial intelligence methods

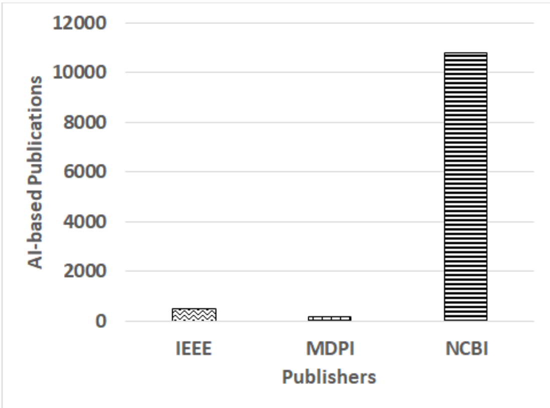
Majority of the existing studies have been reported to use deep learning-based models as a part of AI-approach. CNN is witnessed to be the most frequently adopted deep learning models in combination with various pretrained models viz. XceptionNet, InceptionResNet, VGG16, DenseNet201, VGG201, and EfficientNet-B0. These studies are carried out on both CXR for both COVID-19 and other chest-related diseases too. Apart from CNN, existing system is also witnessed to use random forest (RF), multi-layered perceptron (MLP), support vector machine (SVM), generative adversarial network (GAN), and TL. The recent approaches are observed to mainly emphasize towards addressing identification and classification-based problems associated with CXR images as the core input to the models. Table 1 highlights the outcome of this reviewed recent publications with respect to advantges and limitations.

Table 1. Summary of state-of-art AI methods

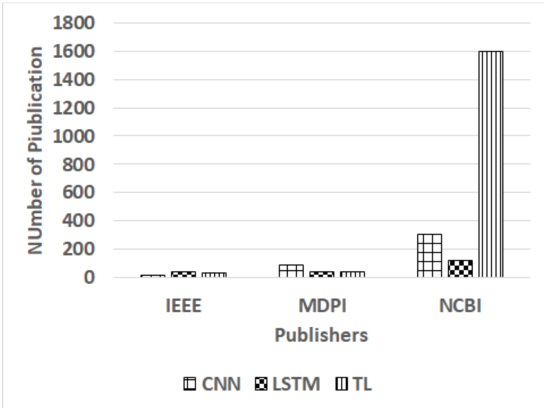
Refs.	Issue identified	AI-methods	Advantage	Limitation
[17]	Excessive radiation during iterative x-ray	Deep neural network (U-Net)	94.3% accuracy, extensive comparison	Lacks focus on computational efficiency
[18]	Unidentified secondary disease	Deep learning model (CNN)	98.72% accuracy, can als classify tuberculosis, pneumonia	Accuracy for non-COVID symptoms still higher compared to COVID symptoms
[19]	Higher processing time for assessing CXR	CNN with 19-layers, stochastic gradient descent	98.85% accuracy, can also classify tuberculosis, pneumonia, fibrosis	Doesn’t address memory demands, slow convergence
[20]	Early detection	Pretrained model prediction via SVM	98.48% accuracy	Lacks interpretability and explainability
[21]	Limited medical resources	CNN for analyzing CXR, joint RF, MLP, and XGBoost for data analysis, model for explainability	77% of accuracy, involves explainability of AI-model	Suffers from high-dimensionality problem, negative interpretability
[22]	Identifying COVID-19 patient	CNN with XceptionNet, InceptionResNet, VGG16	96.77% accuracy, Effective classification for COVID and pneumonia	Computationally intensive process
[23]	Interpretability of AI model	CNN`	90.6% accuracy	Imbalanced data
[24]	Segmentation of infected lesions	Deep Learning network, Region attention	96.32% accuracy	Lack of severity estimation
[25]	Reduced accuracy of detection by standard classification algorithms	CNN with pretrained model	96.75% accuracy, extensive analysis	Doesn’t address exploding gradient during training
[26]	Faster detection of COVID-19 and Pneumonia	DenseNet201, VGG201, EfficientNet-B0	97% accuracy, extensively analzyed, reduced computational complexity	Model loses contextual information due to limited receptors
[27]	Faster identification & classification	Masked R-CNN, Resnet50	92.4% accuracy	Accuracy for non-COVID symptoms still higher compared to COVID symptoms
[28]	Early-stage automated detection	GAN	98-99% accuracy, extensively analyzed	Limited number of samples produced by generator
[29]	Faster identification	CNN with pretrained model	94.13% accuracy	Sensitivity to spatial variability
[30]	Detection of COVID-19	Hybrid deep neural network	99% of accuracy	Higher computational complexity
[31]	Faster identification &classification	Deep CNN model	98.20% accuracy, capable of multi-class classification	Limited invariance
[32]	Faster identification	Compact Convolutional Transformer	99.22% of accuracy	doesn’t facilitate multi-class classification
[33]	Improving AI-model performance	Comparison with and without deep learning model	73.3% accuracy with deep learning	Doesn’t address explainability and interpretability
[34]	Faster screening	CNN, Vision Transformer	98.86% of accuracy	Higher resource demand
[35]	Limited training images	CNN with pretrained model	95-99% of accuracy	Limited to less number of data
[36]	Classification of COVID-19	TL with pretrained models	96% accuracy	Not benchmarked extensively

3.2. Research trends

Investigation towards COVID-19 has taken a faster pace since early 2020 itself with availability of various method which includes both AI-based and non-AI-based methods. However, recent review work carried out has captured more extensive information and hence this section will study only the latest paper publications for the year 2023. The research trend has been observed from IEEE, MDPI, and NCBI publishers while other publishers bear nearly the similar trends. The trend on AI-based publications is shown in Figure 2. Figure 2(a) showcases that there are 11476 research paper that discusses about involvement and contribution of AI-based method over CXR to screen COVID-19 as well as other chest-related and SARS-related disease. Figure 2(b) exhibits that CNN, LSTM, and TL are mostly adopted as AI-based screening schemes in recent studies while there are 1677 publications for TL itself, while there are 410 research papers using CNN. LSTM approaches has received less publications (210). However, a closer look into TL-based approaches showcases less evolution of innovative approaches apart from using pretrained models. From this context, it can be stated that CNN is most frequently adopted AI-based approach.



(a)



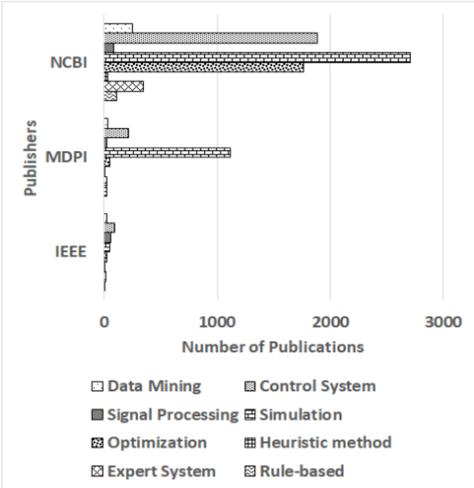
(b)

Figure 2. Trend on AI-based publications over: (a) CXR and (b) CNN, LSTM, and TL

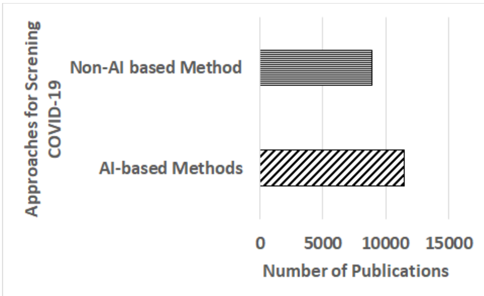
Apart from AI-based approaches, research trend is also explored for non-AI based methods too and are shown in Figure 3. Figure 3(a) shows that simulation-based (3875), control-system (2191), and optimization technique (1829) are extensively adopted non-AI approaches. Less emphasis is found for heuristic methods (43). Other potential non-AI approaches like data mining (309), signal processing (164), expert system (382), and rule-based (149) are adopted in much lower pace. However, a quick insight to Figure 3(b) showcases that AI-based methods (11476) are slightly more evolving in much faster pace compared to non-AI based methods (8942). This outcome of research trend significantly shows that importance of AI approaches is increasing in faster pace while there is also a set of research community where non-AI-based approaches are also continued. Based on this outcome of research trend, it can be stated that future of screening COVID-19 or any other SARs disease holds more scope with AI-based approaches.

3.3. Learning outcomes

The prominent learning outcome of the proposed study is that AI-based approaches are gaining a faster pace of adoption for screening COVID-19 with respect to solving detection and classification problems. The potential problem-solving characteristic of AI-based approaches is realized in all the latest study models where CNN along with pretrained models are witnessed to be solving the problem effectively. The critical observation from the current review work is: majority of the research work implementation methods have considered varied set of CXR dataset; however, there are less consideration of innovative or simplified data augmentation schemes. Owing to this gap, it is noted that accuracy level of majority of implementation is extensively high, while some are quite less, which is a case of either overfitting or underfitting. The researchers have adopted nearly similar scheme where pre-trained deep learning models have been considered targeting towards an effective feature extraction method while CNN has been noted to be frequently adopted deep learning scheme. Hence, there are further more way to go for the existing methodologies to prove its cost effectiveness in terms of its usage in practical ground of implementation in healthcare sector.



(a)



(b)

Figure 3. Recent trend on (a) other approaches and (b) non-AI-based publications and its distinction from AI-based studies

3.4. Discussion

The prominent research gap identified are i) irrespective of availability of CXR dataset, it is noted that they are not suitable towards investigating COVID-19 in larger scale of screening, ii) issues of class imbalance is reported by majority of existing AI-based study models, iii) there are few reported approaches to perform classification of COVID-19 with respect to its severity levels as well as effective multi-classification of stages of COVID-19 is less witnessed too, and iv) majority of the existing approaches using CXR doesn't considers variability attributes associated with it with respect to quality, angle, and positioning of patient while capturing CXR. Apart from this, it is also noted that there is considerably less emphasis towards retaining maximum signal quality while assessing the processed CXR images.

4. CONCLUSION

There has been an undenying fact, that COVID-19 has proven its life-threatening records during the recent pandemic era. In substitution of conventional time-consuming RT-PCR test, there is a need of faster screening approach which could offer a good balance between the higher accuracy from clinical viewpoint and higher computational reliability to compliment a better screening model. The paper presents focused discussion towards some of the most recent AI-based studies towards screening COVID-19 from the CXR images. The contribution and novelty of this review work are as follows: i) the review work offers a highly compact and yet crisp discussion of most recently published journals where AI plays a major role towards screening COVID-19, ii) the discussion of recent AI-based models were carried out with respect to their strength and limiting attributes to offer more measurable effectiveness, iii) a discrete, novel, and highly informative research trend is explored to find usage and practice of various AI-based methods as well as non-AI-based approaches that are not reported yet in any literature till date, and iv) a significant learning outcomes have been presented with respect to critical findings and research gap. The possible limitation of this review is that it doesn't consider any research perspective other than AI and CXR. The future work will be carried out in the direction to address the identified challenges and gap from the current study. A novel AI based approach can be suggested along with image processing in order to offer better diagnosis. The prime implication of this study is to provide a guideline for the need of innovative AI based method and to make an awareness towards the need to address the unsolved problems for better diagnostic tool.

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